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Spectrally-Broad Picosecond Light Source

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Abstract

We describe a fast (35 ps or less), spectrally broad (at least 600 nm) light source for use in characterizing and calibrating photonics equipment. The spectral output of the source is described, and examples of its use are given.

Introduction

In order to properly calibrate photonics instruments such as streak cameras, photomultipliers, and spectral equalizers,[1] the calibration source should have a short temporal duration (picosecond time-scale) and a broad spectral output. This is desirable so that the equipment can be calibrated over a desired spectral region. By using the fact that very-high-power laser pulses can induce non-linear effects in materials (e.g., stimulated Raman scattering and self phase-modulation), one can develop a source with the above-mentioned properties.

The idea of continuum generation through nonlinear processes is not new.[2,3] We describe two systems at Livermore and give some examples of how they are used. We hope this information will prove useful to others who are interested in setting up their own systems.

Description of the systems

System One consists of a pulsed, mode-locked Nd:YAG oscillator followed by a single-pass amplifier and frequency doubler (Fig. 1). The energy output at 532 nm is roughly 3 mJ in a 35-ps pulse. The repetition rate is 10 Hz.

In System Two, the output of a CW, mode-locked dye laser passes through a three-stage dye amplifier pumped by a Q-switched, frequency-doubled Nd:YAG laser. The 1-nJ output from the dye laser is amplified to 0.5 mJ in a 2-ps pulse. Output wavelength is 583 nm; repetition rate is 10 Hz (Fig. 2).

The output of either system is focused through a 20-cm-focal-length lens into a 10-cm-long water cell. The output light is recollimated and sent to the equipment to be calibrated. Precautions should be taken to filter out the fundamental wavelength, as it is quite intense compared to the generated continuum.

The light continuum is created with two processes: stimulated Raman scattering and self phase-modulation.[4] In water, the Raman shift is roughly 3300 cm^{-1} and is responsible for gross shifts in wavelength away from the fundamental.[5] The region between Raman shifts is filled by the process of self phase-modulation. Since the efficiency of frequency generation with self phase-modulation is inversely proportional to pulse width, we would expect the generated continuum to be "smoother" for System Two than for System One.

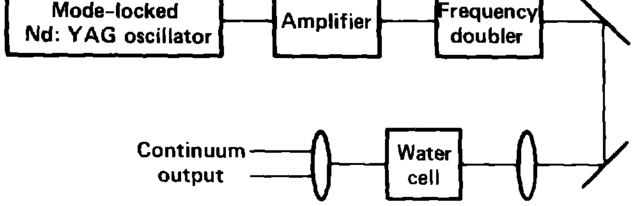

Figure 1. System One: 35-ps pulse.

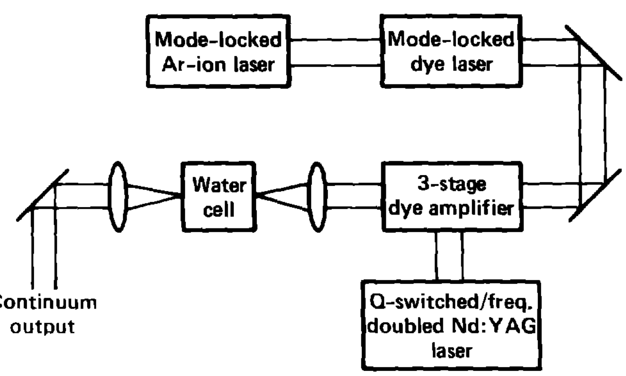

Figure 2. System Two: 2-ps pulse.

In Fig. 3, we show the measured spectrum from System One (solid line) and System Two (circles), using water as the medium. A continuum is generated from 400 to 1000 nm. The output probably extends past these limits but could not be detected due to limitations in the detector. As expected, the spectrum from the 2-ps system is smoother than that from the 35-ps system and has somewhat greater output power over the region. The Raman Stokes and anti-Stokes lines are also indicated on the graph.

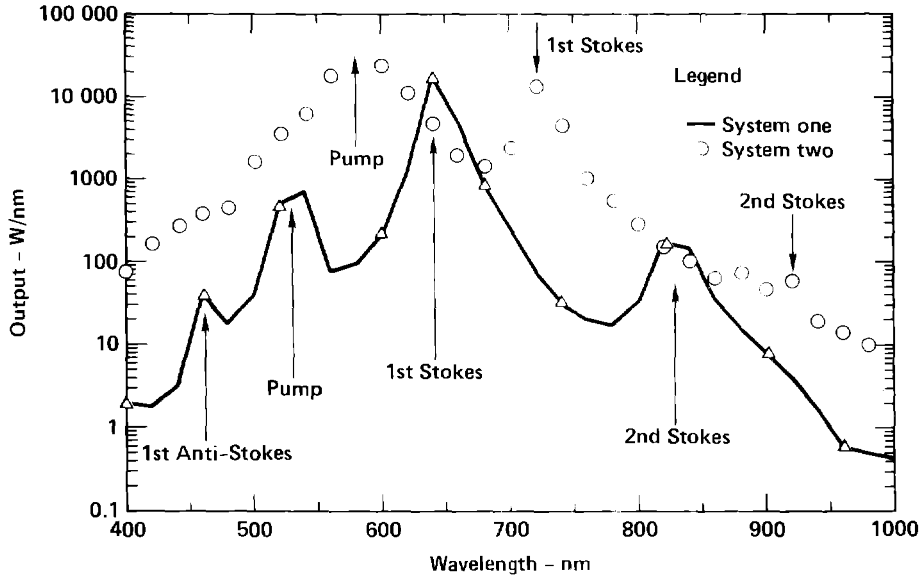

Figure 3. Continuum output from water—35-ps (532 nm) and 2.5-ps (583 nm) inputs.

Examples of use

We use either system to calibrate spectral equalizers and to investigate precursors in optical fibers.

The operation of the spectral equalizer is described in Ref. 1 and will not be detailed here. Basically, the device corrects for material dispersion in optical fibers and allows one to obtain high-bandwidth data over long fiber runs when the optical signal is spectrally broad. The device is used with a streak camera to record the data, and calibrating the system requires a fast, spectrally broad light source.

Figure 4 shows the output of the equalizer in the unequalized mode. The frequency spread shown is from 780 to 820 nm. Figure 5 shows the equalized output. System Two was used for the input light.

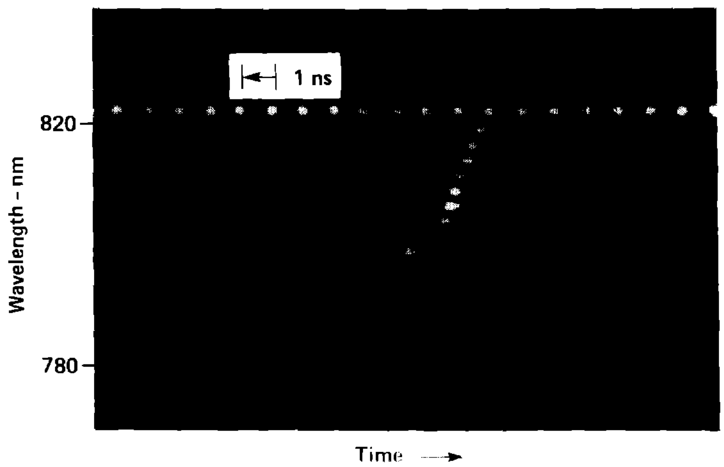

Figure 4. Output of equalizer in unequalized mode (1-GHz comb)

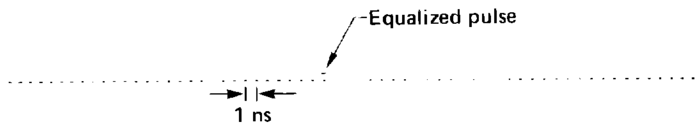

Figure 5. Equalized output.

Prior to the development of the sources, this measurement was done using Cerenkov light generated by a 50-ps pulse of 6-MeV electrons traversing the fiber. The amount of light generated in this fashion is many orders of magnitude below that obtainable from either System One or System Two. We have thus been able to speed up dramatically the calibration of the equalizers.

A second use of the source has been in the investigation of precursors in optical fibers.[6] We have found that in certain high-bandwidth fibers (> 1 GHz-km) precursors develop on short pulses. Figure 6 is a streak camera recording of these phenomena, with Fig. 7 showing an individual pulse with precursors.

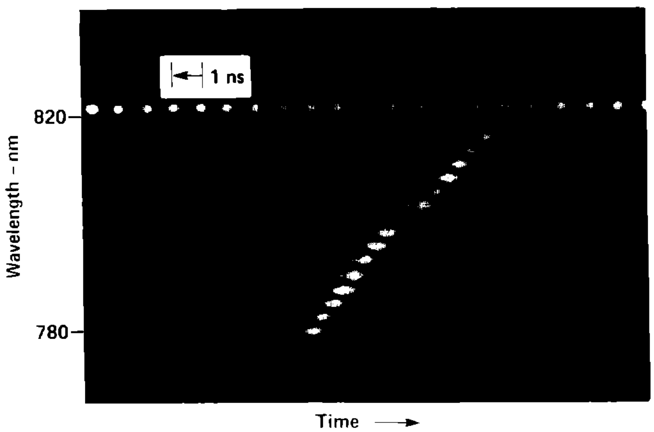

Figure 6. Streak camera recording of precursors on short pulses in a high-bandwidth fiber. (1-GHz comb)

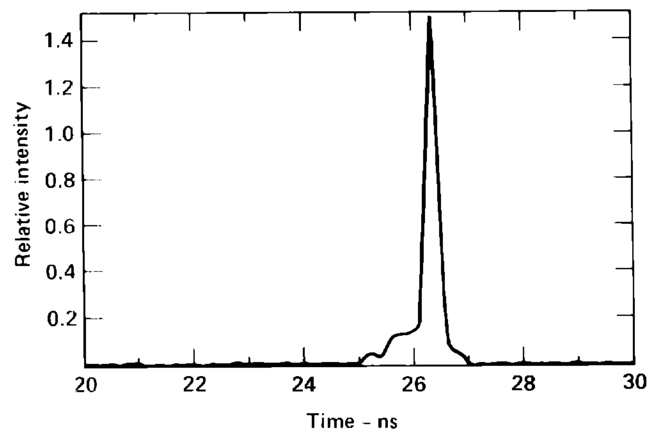

Figure 7. Individual pulse with precursors.

Conclusions

We have described two systems used to provide temporally short, spectrally broad radiation and have described their use in two applications. The output from these sources is a continuum from at least 400 to 1000 nm with spectral intensities greater than 1 W/nm over the entire range (typical intensities are on the order of 100 W/nm). This intensity is sufficient for calibration work on any photonics instrumentation. By choosing different input wavelengths and non-linear media, a variety of output spectra may be obtained.

Acknowledgments

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References

1. R. P. Reedy, F. Roeske, and D. Smith, Review Sci. Inst., to be published.
2. A. Penzkofer and W. Kaiser, Opt. & Quant. Elect. 9, 315 (1977).
3. J. L. Martin, R. Astier, A. Antonetti, C. Minard, and A. Orszag, C. R. Acad. Sci. Ser. B *289B*, 45 (1979).
4. See Y. R. Shen, *Principles of Nonlinear Optics*, (Wiley, New York, 1984) p. 324.
5. J. Griffiths, J. Chem. Phys. *60*, 2556 (1974).
6. F. Roeske, Lawrence Livermore National Laboratory, Livermore, Calif., private communication (1985).